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PAYLOAD DEPLOYMENT SYSTEMS AND ADVANCED MANIPULATORS

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This paper presents the results of discussions on future development of avionics to support payload deployment systems and advanced manipulators. The discussions summarized here were held during the Space Transportation Avionics Technology Symposium in Willaimsburg, Virginia on Nov 7-9, 1989.

The quad charts for this subtopic were generated by C. Gott, D. Homan, and E. Bains/NASA-JSC, P. Swaim/MDSSC, and R. Haken/TRW. During the symposium significant contributions were also made by C. Price/NASA-JSC and M. White/RI-D.

Symposium partiucipants agreed that this subpanel would have benefited from more participation by users. It was suggested that inputs from Shuttle payload users should be incorporated, either by direct discussions with users or by incorporating comments from users as kept by Payload Accomodations. JPL, Goddard, and Langley, as builders of payloads, and the Space Station Utilization Office could also provide useful inputs. Other potential users for future systems should also be identified as early as possible to determine what they anticipate their needs to be.

Symposium participants also recognized that payload deployment is normally not a safety critical area, and as such, is vulnerable to budget cuts that defer costs from development to operations. This does give opportunities for upgrades of operational systems, but these must be very cost effective to compete with vehicle requirements that enhance safety or increase lifetime.

The quad charts prepared for the symposium are shown in Figures 1 and 2. These present progress and needs in five major areas. These are (1) Fault tolerance and redundancy management; (2) Hardware upgrades to increase longeviety; (3) Development of basic capability for future systems; (4) Improvements to enhance crew effectiveness/autonomous operations; and (5) Enhancements that decrease sensitivity of the base vehicle to manipulator operations.

The quad charts showed improved redundancy/ fault tolerance as a major objective for payload deployment systems. Discussion at the symposium identified this as a major need for the Shuttle RMS, but one that is not in work at present. Redundancy management as applied to the Shuttle GN&C is considered desirable for use with SRMS, but there is no activity in this area at present. In addition, no future programs were identified as having active programs to incorporate redundancy management into their designs; adding this to the SRMS would be likely to bring it into future programs also.

Hardware upgrades that could reduce stress on the manipulator were also considered a major source of system lifetime

improvement. While most hardware changes to manipulators may not be in the area of avionics, load sensing/relief is an active and potentially valuable avionics upgrade. A load sensor for the SRMS is currently under development by JPL, and successful demonstation of this capability would provide a valuable leadin for future ssystems. This capability would be extremely valuable for autonomous systems such as would be needed for unmanned flights to Mars.

The third area, development of basic capability for future systems, has a great deal of activity for space station, but very little activity for other future systems. Space station work has included development and evaluation of manipulator control laws, and future work is anticpated to include path planning algorithms, collision avoidance algorithms, and control for more than one manipulator in parallel operation. While there is virtually no active work for future systems other than space station, the requirements for those systems must also be defined. The existing shuttle RMS software and the space station work, both that currently being done and that being planned, provide a solid base for other systems when requirements become firm.

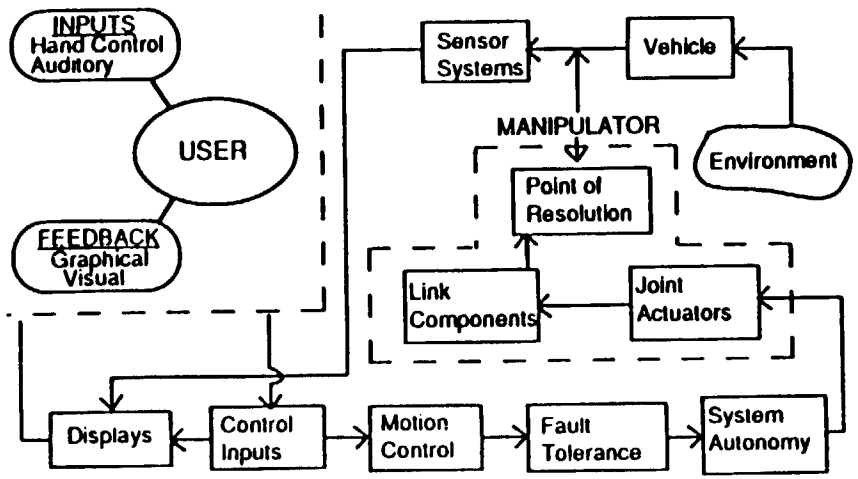
Many improvements to enhance crew effectiveness or to support autonomous operations were suggested. The quad charts identified path planning and collision avoidance as reducing training requirements and on-orbit planning. Collision avoidance was also mentioned in discussion as a requirement for systems operating outside a fixed work cell, particularly with multi-arm operations. Improvements in information display were also discussed, and were agreed to have high potential payback. EVA requirements could be greatly reduced with dexterous handling, but this has a high initial cost that may make it hard to sell. Areas that have already shown major accomplishments in enhancing crew effectiveness in ground tests include helmet mounted displays and stereoscopic vision systems. Other systems that were mentioned during symposium discussions as having potential for great benefit without great cost included control of cameras by voice or by automatic tracking of a selected point such as the End Effector.

Finally, pre-mission planning of base vehicle control could be made a great deal simpler and cheaper by reducing the response of the base vehicle to manipulator operations. Changes to the Shuttle on-orbit DAP have already been approved to improve vehicle control during SRMS operations, and further improvements are possible. This area is also under active investigation for space station. The need and benefits from this activity seem clearly established.

In summary, redundancy management for the shuttle RMS was mentioned as a major need that is not currently being addressed. For future systems, collision avoidance, simpler user interface with manipulators, and incorporation of force feedback systems were mentioned as major areas needing work.

SPACE TRANSPORTATION AVIONICS TECHNOLOGY SYMPOSIUM
PAYLOAD ACCOMMODATION
P/L DEPLOY SYSTEMS & ADV. MANIPULATORS

P/L DEPLOYMENT SYSTEMS & ADV MANIPULATORS



MAJOR OBJECTIVES:

* Reduce pre-mission planning
  - Improved redundancy / fault tolerance
  - Optimal path planning
* Increase crew productivity
  - Autonomous operations frees crew for other tasks
  - Path planning / collision avoidance reduces training requirements and on-orbit planning
  - Dexterous handling reduces EVA requirements
* Increase hardware longevity
  - Load sensing / relief reduces joint / structural loads
* Reduce base vehicle attitude control system sensitivity to manipulator operations

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D. Homan / JSC / FM8

E. Bains / JSC / EH23

J. Davidson / MMC

FACILITIES:

* Integrated Graphics and Operations Analysis Laboratory (IGOAL)
* Draper Remote Manipulator System Simulation (DRS)

MAJOR MILESTONES (1990 - 1995)

* Major programs to support
  - NSTS
  - Space Station Freedom
  - Lunar Base / Mars Mission Scenarios
* Programmatic Issues
  - Manipulator design and operations requirements
  - Integrate vehicle / manipulator control system design
  - Vehicle assembly and on-orbit processing
  - Lunar base construction
  - Mars surface operations
* Simulation development for state-of-the-art hardware & software
  - Kinematic
  - Dynamic
* Evaluate advanced technologies
* Develop systems concepts
* Evaluate capabilities / cost / benefits

SPACE TRANSPORTATION AVIONICS TECHNOLOGY SYMPOSIUM
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P/L DEPLOY SYSTEMS & ADV. MANIPULATORS

TECHNOLOGY ISSUES:

- Planning and Control Algorithm Development
  - Path planning
  - Collision avoidance
  - Redundant manipulator control
- Sensor / Effector technology
  - Dexterous manipulators / force feedback systems
  - Robotic vision / tracking
- Interaction of deployment device with vehicle control
- System performance
- System reliability

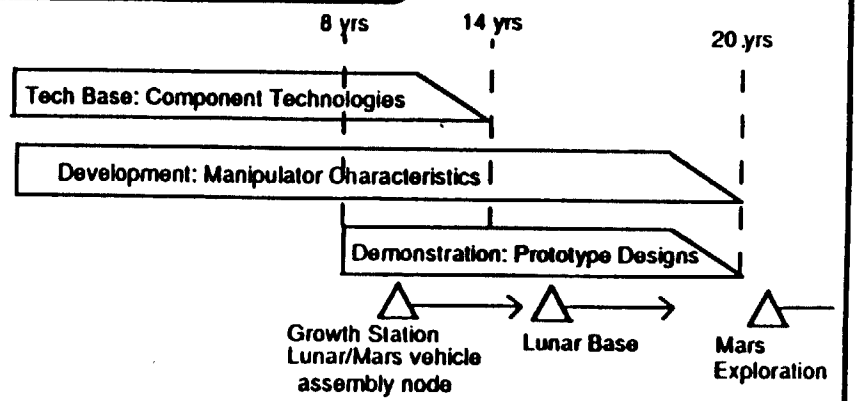
CANDIDATE PROGRAMS:

- Shuttle Remote Manipulator System
- Flight Telerobotic Servicer
- OMV
- Lunar Base
- Mars exploration
- EVA Retriever
- Special Purpose Dexterous Manipulator SPDM
- Mobile Servicing Centre

MAJOR ACCOMPLISHMENTS:

- Development of kinematic and dynamic simulators for generic remote manipulator systems and vehicle interaction
- Manipulator control law development and evaluation
- Telepresence systems technology investigations
  - Helmet mounted display
  - Stereoscopic vision systems
- Man-in-the-loop part task simulators
  - Shuttle Remote Manipulator System
  - Space Station Remote Manipulator System
  - Flight Telerobotic Servicer

SIGNIFICANT MILESTONES:



- Component technologies make up total manipulator system
- Robotic characteristics enhance manipulator operation and performance
- Prototype designs evolve over several generations